

# JPL Activities in AI and Data Science

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**2nd Workshop on Artificial Intelligence and Data Science for Space and Earth Science**

*February 9, 2021*



**Jet Propulsion Laboratory**  
California Institute of Technology

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Government sponsorship acknowledged.

# AI for Data Science

*with contributions from*

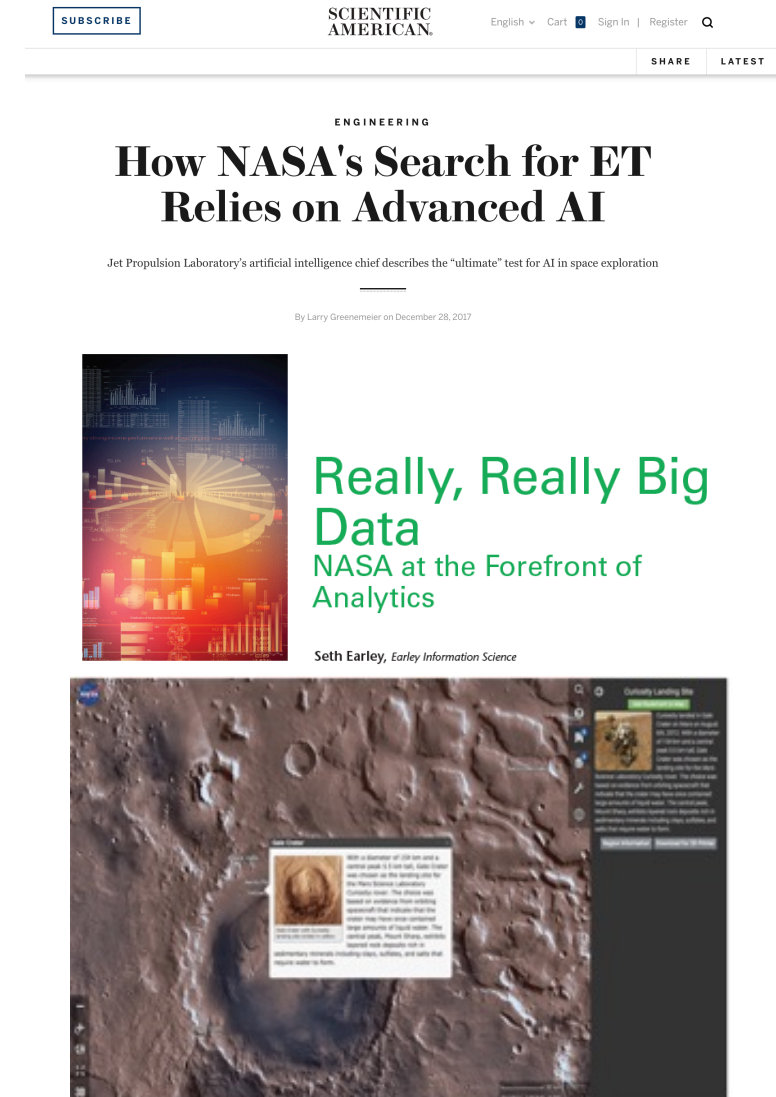
**Dan Crichton**

*JPL Leader*

*Center for Data Science and Technology*

# Tackling Data Science Challenges at JPL

- JPL is engaging Data Science and AI / ML technologies and methodologies across science, engineering, and mission operations
- JPL has a Data Science Working Group focused on building and implementing an institution-wide strategy for Data Science and AI / ML
- Over 50 pilot projects, larger projectized efforts, plus partnerships and events.

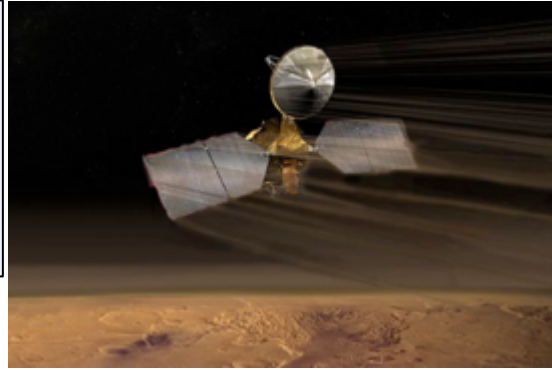


# Data Lifecycle Model for NASA Missions

From Onboard Computing to Scalable Data Analytics

## Emerging Solutions

- *Next-Generation Flight Computing*
- *Onboard Data Analytics*



*Observational Platforms and Flight Computing*



## Emerging Solutions

- *Intelligent Ground Stations*
- *Agile Mission Operations*



*Ground-based Mission Systems*



## Emerging Solutions

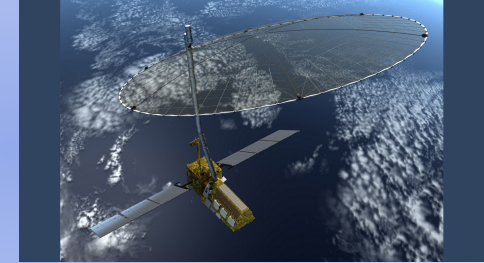
- *Data-Driven Discovery from Archives*
- *Scalable Computation and Storage*



*Interactive Analytics and Visualization and Decision Support*



SMAP (Today): 485 GB/day

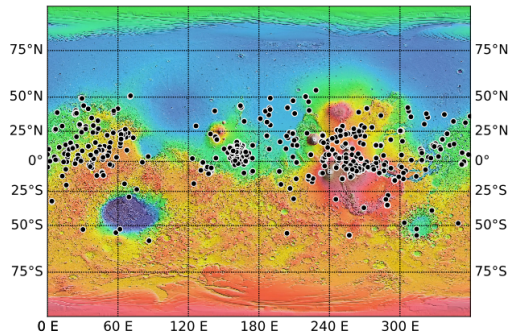


NISAR (2021): 86 TB/day

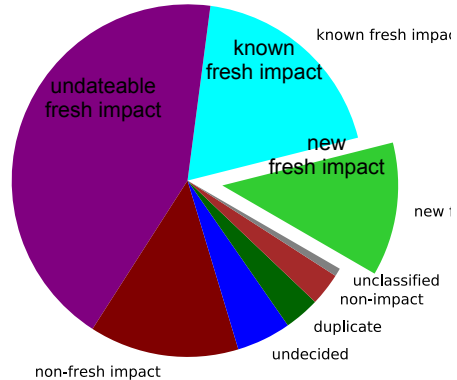
**Scaling Pressures Expose the Need for an Integrated End-to-End Data and Computational Architecture**

# First time machine learning has been used to find previously unknown craters on the Red Planet

Top 1131 classifier candidates

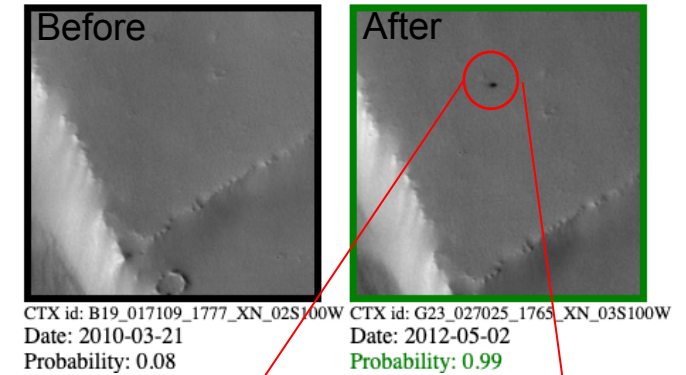


Top 400 after scientist review



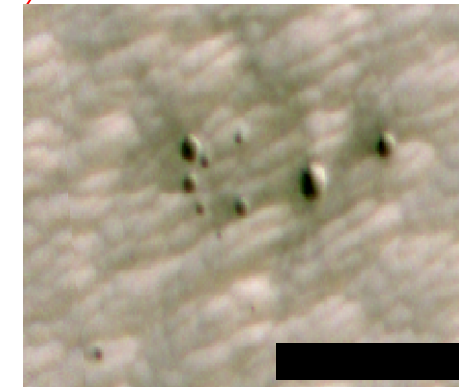
- COSMIC is a capability to monitor the entire Martian surface for transient science events, targeted to future onboard use
- Tested on a 112,000 image database to search for fresh impacts
- Machine learning can help accelerate scientific discoveries
- NASA/JPL Press release picked up by Universe Today, Analytics Insight, Vice, NPR, and Google Space News

First new discovery found



Follow-up HiRISE view

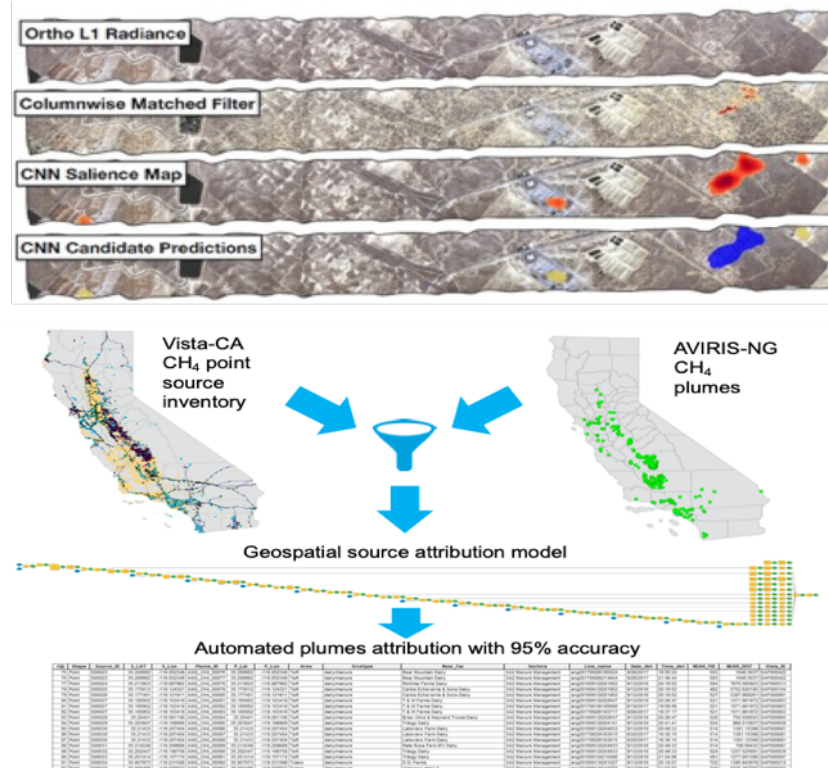
Can you find the fresh impact in this image?



# AI and ML Applied to Earth Science

## Deep Learning for Methane Point Source Detection

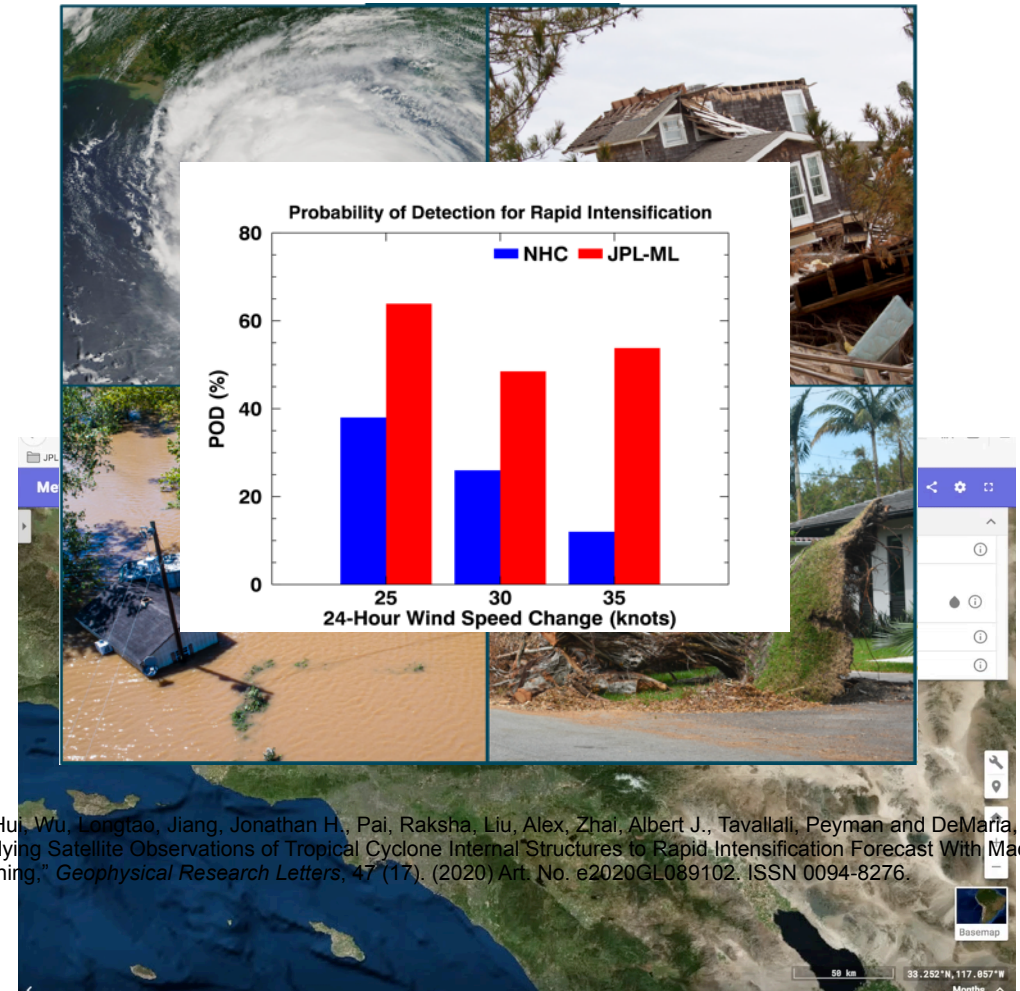
*Reduced latency from  
3 months to 48 hours*



Duren RM, Thorpe AK, Foster KT, Rafiq T, Hopkins FM, Yadav V, Bue BD, Thompson DR, Conley S, Colombi NK, Frankenberg C, McCubbin IB, Eastwood ML, Falk M, Herner JD, Croes BE, Green RO, Miller CE. "California's methane super-emitters." *Nature*. 2019 Nov; 575(7781):180-184. doi: 10.1038/s41586-019-1720-3. Epub 2019 Nov 6. PMID: 31695210.

## Machine Learning Assist to Predicting Hurricane Intensity

*Improved forecasting in the  
Atlantic basin to >70%*



Su, Hu, Wu, Longtao, Jiang, Jonathan H., Pai, Raksha, Liu, Alex, Zhai, Albert J., Tavallali, Peyman and DeMaria, Mark. "Applying Satellite Observations of Tropical Cyclone Internal Structures to Rapid Intensification Forecast With Machine Learning," *Geophysical Research Letters*, 47(17). (2020) Art. No. e2020GL089102. ISSN 0094-8276.

# AI for Autonomy

*with contributions from*

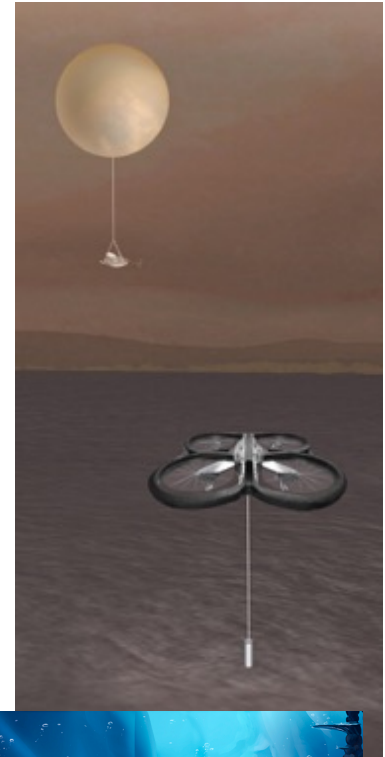
**John Day**

*JPL Leader*

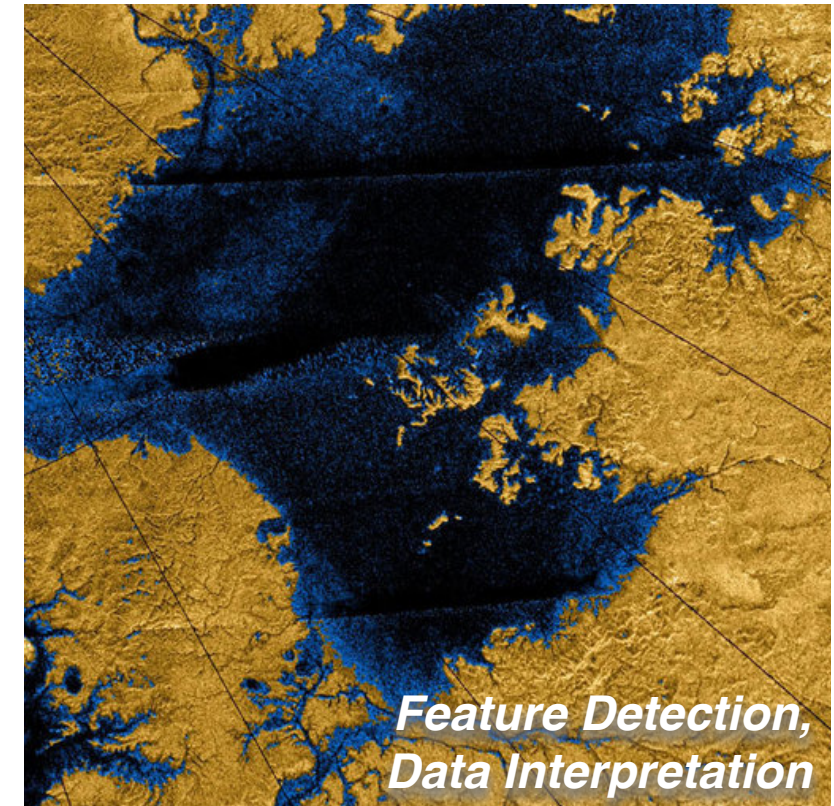
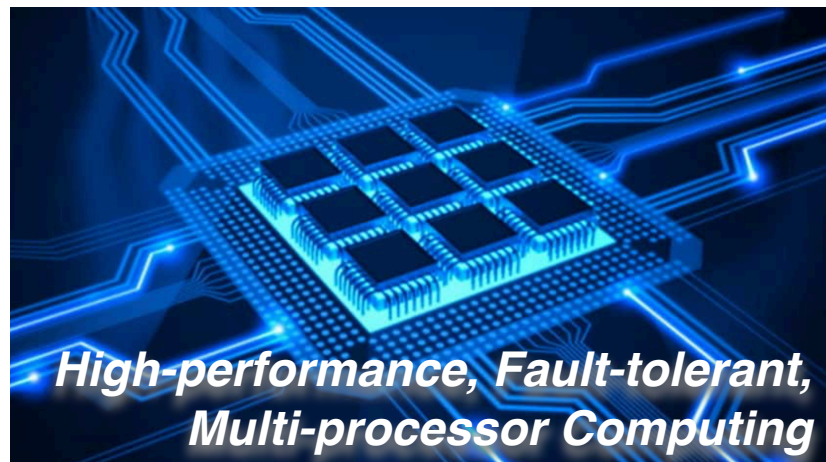
*Center for Autonomy*

# Vision for the Future of Autonomy at JPL

- Space exploration involves spacecraft operating in harsh and unforgiving environments
- JPL is pioneering resilient, self-aware, and autonomous systems able to weigh risk and make decisions locally to ensure that tomorrow's missions are a success
- Key characteristics of future missions:
  - Goal-directed operations, allowing operators to focus on objectives and oversight
  - Self-sufficient planning, scheduling, and control, including management of resources and redundancy, and recovery from anomalies
  - Real-time assessment of situations given set of objectives and utilizing models of system and environment
  - Capabilities for learning and model adaptation based on observations of system and environment

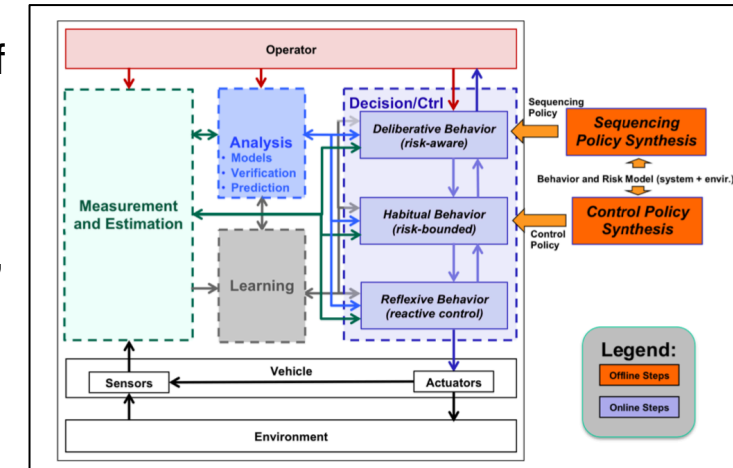


# Key Capabilities for Autonomous Systems

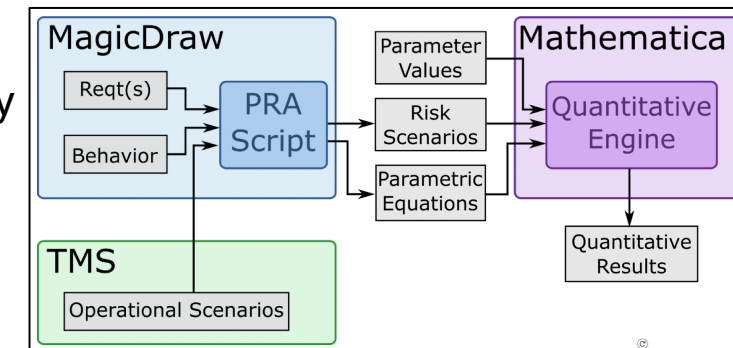


# Autonomy Focus Areas

- Architecture
  - Mission-wide evolvable architecture that enables the integration and deployment of state-of-the-art control and reasoning technologies
- Methodology
  - Processes and tools for assembly, coordination, and analysis of information in a systematic fashion that ensures completeness and accuracy, resulting in a reliable, affordable, operable system
- Computing
  - High-performance, fault-tolerant, multi-processor computing platforms
- Assessments and guarantees of system behavior
  - Enabled by principled design techniques and advancements in simulation and formal methods
- Iterative development
  - Iterative development of operational capabilities via rapid prototyping, progressively increasing the scope of the deployed autonomy capability
- Partnerships and collaborations
  - Leverage external capabilities in autonomy, AI and related technologies



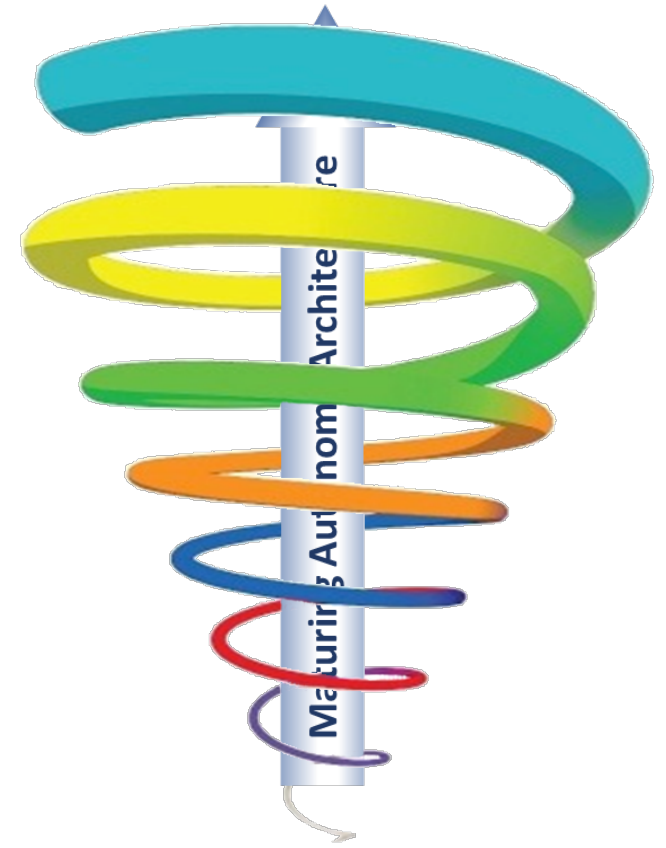
Resilient Spacecraft Executive Architecture



Model-based Probabilistic Risk Assessment

# Staged Evolution of Capability

- Stage 1: “Resilient System”
  - System performs resource management and health management functions. Executes “tactical” activity plans provided by operations team. Uses and adapts models of internal state. Control via closed-loop commanding. Adapts detailed plan to address minor anomalies.
- Stage 2: “Independent System”
  - System generates tactical activity plan based on science directives (“strategic plan”) provided by science team. Uses and adapts models of internal state and environment. Reduced mission operations team.
- Stage 3: “Self-Directed System”
  - System develops science strategic plan and tactical plans based on high-level objectives. Responds to novelty by adjusting plans within context of objectives. Reduced science operations team.



# The Importance of Partnering

The background of the slide is a dark blue, futuristic image. It features a curved horizon line, possibly representing the Earth, with a complex network of glowing blue lines and nodes that resemble a circuit board or a global communication network. A prominent, bright yellow and orange energy burst or starburst is located on the right side, radiating light across the scene. Several smaller, glowing yellow and blue nodes are scattered throughout the network.

# Partnering Strategy

- **NASA**

- Working with HQ – SMD and DTX, and Centers – GSFC, ARC, LaRC... on Strategy for AI / ML activities for science and enterprise
- GSFC – Center for Helioanalytics, HPC benchmarking, climate simulation...

- **Academia**

- Caltech Joint Center in Data Science
- Training of student interns using JPL use cases
- Collaborations with UC, CMU, MIT

- **Government**

- Interoperability of archives
- Engagement of technologies and data scientists across agencies
- Collaboration with MIT Lincoln Lab

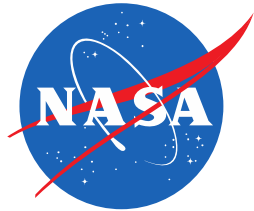
- **Industry / Open Source**

- Leverage and collaboration on big data technologies and cloud services
- Form public-private research partnerships
- Collaborations with Amazon Web Services and the Apache Foundation



CENTER FOR DATA-DRIVEN DISCOVERY





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